ORIGINAL ARTICLE

# *Children's Exposure to Traffic and Risk of Pedestrian Injury in an Urban Setting*

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**Abstract.** *Pedestrian injuries to children represent a major urban health problem in the United States. Thousands of children each year are struck by moving motor vehicles; such collisions result in numerous hospitalizations and deaths. At particular risk are young school-age children between the ages of 5 and 9 years.*

*Using a survey methodology, we collected data regarding the method by which children in an urban setting travel to and from school, in addition to the number of streets they cross in a typical school day. This information was compared with data from police records on street intersection locations of pedestrian collisions.*

*There is a wide variation in the number of streets children cross in 1 day, calculated as the number of streets crossed in the entire day, not only those crossed to and from school. Children whose parents own a car and home cross an average of 3.7 streets per day, whereas children whose parents do not own both a car and home cross an average of 5.4 streets per day; this difference is highly significant ($P < 0.0001$). The largest differences in traffic exposure are between families reporting car-and-home ownership ($x = 3.70$ streets) versus those who do not own both a car and home ($x = 5.39$ streets) (Mann-Whitney $= -5.5$, $P < 0.0001$).*

*There is a significant correlation between the proportion of children driven home from school and the rate of pedestrian injury in different regions of Baltimore. In areas where children are driven home, rates of pedestrian injury are significantly lower, whereas in areas where children walk home, rates of pedestrian injury are high ($r = -0.79$, $P < 0.01$).*

*This study underscores the importance of adapting the child's environment to prevent injury. Interventions that alter the nature of the hazard are indicated. Changing the environment may ultimately prove more useful than attempting to change children's behavior.*

Among the many hazards present in the urban setting, one of the deadliest is the presence of automobile traffic on busy streets.

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Pedestrian injuries—the physical trauma incurred when a moving motor vehicle strikes a person—are a leading cause of death and disability among children under 14 years of age in the United States. At particular risk are children between the ages of 5 and 9 years who live in urban areas.[1,2] There are approximately 50,000 child pedestrian injuries annually in the United States, of which approximately 18,000 children are hospitalized, 1,800 die, and 5,000 have long-term sequelae.[1] In the city of Baltimore (population 700,000), more than 200 children in the 5-to-9 age group are struck by moving motor vehicles each year; this results in five deaths annually in this age group.[3]

Because pedestrian injuries occur when children "dart out" into the street, preventive efforts have concentrated on educating children to be safer pedestrians. Much of the literature on the patterns of pedestrian injuries has focused on characteristics of the child:[1] males have nearly twice the rate of females;[2] the peak age among children is between 5 and 9 years;[3] and children from lower socio-economic backgrounds have a greater risk of injury than those from higher socio-economic backgrounds.[4–10]

Pedestrian injuries, however, can be viewed as an interaction among three different forces: the agent or injury-causing force (car/driver), the host (the child), and the environment (size of street, crossing devices, weather conditions).[11] The "agent" causing pedestrian injuries is fast-moving traffic, a common element of busy streets in an urban setting. The risk of death in a pedestrian collision is proportional to the speed of a moving vehicle.[12] Urban traffic is generally designed for the convenience of drivers who must navigate through a city at the highest speed possible. Traffic patterns are often not planned with consideration for the population of children walking across busy streets.

Fewer studies have examined the risk of children being injured by a pedestrian collision as a function of fast-moving traffic.[4,14,15] These studies have found a relationship among the quantity of traffic volume, posted speed limit, and rate of pedestrian injuries. However, although such studies show correlations between different environmental characteristics and pedestrian injury rates, they have not measured the actual exposure of children to traffic and its relationship to pedestrian injury.

This study was conducted to gather descriptive data on the number and types of streets children in a city cross each day. This information was compared with an existing record of pedestrian injuries in Baltimore. Ecological associations were derived to assess possible relationships. Because neighborhoods differ in wealth and other environmental factors, differences across neighborhoods were an especially important element of this research. With such information, better strategies for prevention of pedestrian injuries in school-age children can be developed.

## *Materials and Methods*

### Study Design

We used a three-page booklet-style survey to gather information related to the numbers and sizes of streets first- and fourth-grade children cross in a typical school day. The information gathered from the survey on children's exposure to traffic was then compared with locally available data on pedestrian injury rates in this age group. The survey was implemented over 2 weeks in late May and early June, 1995.

A list of all elementary schools within the Baltimore city limits, both public and parochial, was created as a sampling frame. Clusters of census tracts were grouped into one of ten "regions" defined by major streets and expressways as boundaries. Elementary schools were then designated as belonging to a region based on physical location within the city. To ensure geographic representation of various neighborhoods, the sampling frame was ordered by region, and a systematic sampling mechanism was used so that a minimum number of schools from each region were certain to be included.

A total of 26 schools (22 public, 4 parochial) were selected and agreed to participate; two additional public schools declined to be a part of the study. Permission to distribute surveys to the children was obtained by the superintendents of the public and parochial school administrations. After contacting the selected schools' principals, multiple survey forms were delivered to each school. The purpose of the study was explained to the principals by the researchers, who also provided instructions as to the distribution of the forms to teachers. Specific conditions of the agreement with school administration officials required no contact between the researchers and the individual children or teachers. The only contact the researchers had was with the school principals.

At the prompting of the principals, first- and fourth-grade teachers instructed children to fill out the survey at home with their parents and return them to school. After the survey forms had been returned to the teacher by the children, principals collected the survey forms from the teachers. The researchers returned to each school to pick up the survey forms and gather any informal comments from the principals regarding issues of the survey implementation.

In summary, surveys passed from the researchers to principals to teachers to children and finally to parents, who then returned the completed forms back to their children to deliver to their teachers. Principals collected the surveys from the teachers, and the researchers collected completed forms from the principals.

Two public schools had difficulties in distribution and collection of the survey forms, and were unable to provide data for the survey. Twenty-four schools were represented in the final study.

**Survey Instrument**

The survey instrument was adapted from a current international effort to collect information on several issues related to children's exposure to traffic (Ian Roberts and collaborators of the International Study of Children's Exposure to Traffic, personal communication). The booklet was printed on high-quality paper in colored ink to encourage response. The front page contained a disclosure letter to all parents, stating that their responses would be anonymous and that they could not be identified in any way based on their responses to the questions. The letter also indicated that participation was voluntary and that non-participation would not affect the respondent or their child's access to any school resources. No financial or other incentive was provided for participation. The disclosure letter and the survey instrument were approved by the Committee on Human Research of the Johns Hopkins School of Public Health.

The survey asked the parents, "How many streets of the following type did your child cross today?" Possible choices of responses included: "small streets (almost never have to wait to cross)," "medium streets (sometimes have to wait to cross)," "main streets (almost always have to wait to cross)," and "main streets with stop lights".

This set of questions was repeated four times, preceded by the headings "Before going to school," "On the way to school," "Coming home from school," and "After school." Respondents were also asked to note how children got to and from school from a list of choices (e.g., driven, walk with other children); this question was needed, as children who are driven to school are not exposed to traffic as pedestrians. The remainder of the survey asked the respondents demographic questions, including their relationship to the child (e.g., father, mother, grandparent), the child's age, and gender. Parents were also asked to state whether they owned a motor vehicle and whether they owned a home.

The data collected in the survey are based on care giver report. For reasons of respondent confidentiality there was no opportunity to validate the responses. However, the questions are neither sensitive in nature nor prone to subjective interpretation. We, therefore, have no reason to believe there are any systematic biases in reporting.

**Pedestrian Injury Data**

Pedestrian injury data were taken from 1993, the most recent year available. The Baltimore Bureau of Transportation, Division of Traffic Safety, collects pedestrian injury data from motor vehicle accident reports received from the Baltimore City Police Department. The pedestrian injury database includes information on the age of the person injured and the exact street intersection where the pedestrian-motor vehicle collision occurred. The injury data on the subset of children ages 5 to 10 years was compared with the survey information on exposure to traffic. The intersection location of each pedestrian collision was geo-coded into 1 of the 10 city regions in this study. Using the most recent census data available, denominators for total number of children in this age group were obtained and used in calculating rates of pedestrian collisions.

### Statistical Methods

For analyses involving categorical independent and dependent variables, the chi-square statistic was used. For analyses involving a non-normally distributed outcome, either the Mann-Whitney *U* test (for two groups) or Kruskal-Wallis test (for more than two groups) was used to compare group differences. For comparisons of two continuous variables, correlation coefficients were calculated.[16]

## *Results*

### Responses and Respondents

Of the 3,285 survey forms given to the 24 participating schools, 861 completed forms were returned, for a response rate of 26%. This percentage varied across schools, but was consistent across the 10 regions of the city constructed for the sampling frame. The response rate was higher for the four parochial schools (44%) than for public schools (25%). Table I summarizes characteristics of the respondents to the survey.

### Methods of Getting to and From School

Table II describes the ways children get to and from school each day. Approximately 55% of children walk to school in the morning; the other 45% are driven by car or bus/public transportation. In the afternoon, 64% walk home, whereas 36% are driven by car or bus/public transportation. Three-quarters of children get to and from school by the same means, whereas one-quarter travel by different means during the two times of the day. Twenty-eight percent of children are driven to and from school.

**TABLE I**
CHARACTERISTICS OF RESPONDENTS AND THEIR CHILDREN ($N$ = 861)

| | |
|---|---|
| Respondents | |
| Education level | |
| High school or less | 48% |
| Trade/vocational school | 12% |
| Some college | 23% |
| College/graduate school | 17% |
| Relation to the child | |
| Mother | 85% |
| Father | 8% |
| Grandparent/other | 7% |
| Children | |
| School type | |
| Public school | 90% |
| Parochial school | 10% |
| Gender | |
| Female | 58% |
| Male | 42% |
| Age | |
| 5 to 7 years | 51% |
| 8 to 11 years | 49% |

Whereas a majority of public students walk (58%), most parochial students are driven (67%) ($X^2$ = 39.2, $df$ = 4, $P$ < 0.0001). As public and parochial schools differ in the percent of respondents reporting car-and-home ownership (37% vs. 84%, respectively), public and parochial students are significantly different in the ways they get to and from school.

There appears to be no difference in the ways boys and girls travel to and from school ($X^2$ = 1.9, $df$ = 4, $P$ = NS). In contrast, there are significant differences across age in the ways which children get to and from school. Older children tend to walk more than younger children, who tend to be driven more ($X^2$ = 88.5,

**TABLE II**
METHODS OF GETTING TO AND FROM SCHOOL

| | Getting to School in the Morning | Coming Home From School in the Afternoon |
|---|---|---|
| Walk alone | 7% | 6% |
| Walk with other children/teenager | 23% | 31% |
| Walk with an adult | 25% | 27% |
| Car | 39% | 30% |
| School bus/public transportation | 6% | 6% |

*df* = 24, $P < 0.0001$). This trend is especially evident in the percent of children who walk alone—3% of first graders walk alone to school; 11% of fourth-graders walk to school unaccompanied.

Very few children walk somewhere else before going to school in the morning (5%); a slightly larger proportion of children take additional walks in the afternoon after coming home from school (15%).

## Children's Exposure to Traffic

There is a wide variation in the number of streets children cross in 1 day, calculated as the number of streets crossed in the entire day, not only those crossed to and from school. Thirty-five percent of children cross five or more streets; another 41% cross between one and four streets. On average, children in Baltimore cross 4.61 streets per day (95%CI: 4.26–4.96), with one being a large main street. After removing the 28% of children who are driven to and from school from the calculation (who cross almost no streets), the average number rises to 6.19 streets per day for each child (95%CI: 5.76–6.62).

Patterns of traffic exposure parallel the methods by which children get to and from school. There appear to be no gender differences in traffic exposure; both boys and girls cross between four and five streets per day (Mann-Whitney = −0.6, $P$ = N.S.). Age is a significant predictor of the number of streets children cross (see Table III), with younger children crossing fewer streets (Kruskal-Wallis = 13.7, $df = 6$, $P < 0.05$). However, this relationship is not significant after removing children who are driven to and from school (Kruskal-Wallis = 8. 1, $df = 6$, $P$ = NS). Younger children are more likely to be driven, which explains this effect. The largest differences in traffic exposure are between families reporting car-and-home ownership ($\bar{x} = 3.70$ streets) versus those who do not own both a car and home ($\bar{x} = 5.39$ streets) (Mann-Whitney = −5.5, $P < 0.0001$). The former group tends to drive their children, and thus children in families with a car are exposed to less busy traffic as pedestrians.

**TABLE III**
DIFFERENCES IN STREETS CROSSED, BY AGE

| Age of Child (years) | Percent Driven to & From School | Percent Who Walk Alone | Streets Crossed in 1 Day* | Streets Crossed after Removing Children Driven to and from School[a] |
|---|---|---|---|---|
| Six | 32 | 2 | 3.96 | 5.53 |
| Seven | 33 | 2 | 4.21 | 6.18 |
| Eight | 21 | 5 | 4.08 | 5.26 |
| Nine | 27 | 10 | 5.07 | 6.67 |
| Ten | 21 | 9 | 5.59 | 6.90 |

Children ages 5 and 11 years omitted from table because of small group size.
* $P < 0.05$.
[a] $P$ = Non-significant.

## City Region Differences

The 10 regions created for this study show large differences in car-and-home ownership. In the three wealthiest regions, more than half of children live in families who own both car and home. In the four poorest regions, less than one-quarter of children live in such households. Along with differences in car-and-home ownership, the 10 regions of the city show large differences in traffic exposure. In some areas, children cross a few large main streets on their way to school, whereas in other areas children cross many small non-busy streets. These differences are summarized in Table IV. After ordering the regions by wealth (as measured by

**TABLE IV**
DIFFERENCES IN STREETS CROSSED, BY CITY REGION ($N$ = 10)

| Region | Percent of Respondents Car-and-Home Owners | Percent of Children Driven to & from School | Streets Crossed per Day* | Proportion that are Main Streets* | Streets Crossed, Removing Children who are Driven* |
|---|---|---|---|---|---|
| 1 | 58 | 36 | 3.52 | 7% | 5.16 |
| 2 | 53 | 28 | 3.51 | 6% | 4.18 |
| 3 | 53 | 30 | 4.56 | 12% | 6.19 |
| 4 | 49 | 31 | 3.76 | 16% | 5.26 |
| 5 | 48 | 46 | 2.20 | 8% | 4.02 |
| 6 | 42 | 25 | 7.16 | 17% | 9.28 |
| 7 | 24 | 21 | 4.53 | 11% | 5.55 |
| 8 | 21 | 13 | 5.31 | 19% | 6.38 |
| 9 | 20 | 8 | 5.22 | 9% | 5.70 |
| 10 | 19 | 12 | 5.70 | 21% | 6.36 |

Note: Regions ordered from highest wealth (car and home ownership) to lowest wealth (car and home ownership)
* $P < 0.0001$.

**TABLE V**
PEDESTRIAN INJURY RATES, BY REGION

| Region | Number of injuries | Rate (per 1,000 children) |
|---|---|---|
| 1 | 14 | 2.4 |
| 2 | 232 | 3.5 |
| 3 | 22 | 8.7 |
| 4 | 8 | 2.6 |
| 5 | 15 | 1.4 |
| 6 | 5 | 0.9 |
| 7 | 30 | 9.2 |
| 8 | 33 | 9.7 |
| 9 | 43 | 8.3 |
| 10 | 60 | 13.4 |
| Total | 254 | 5.0 |

percentage of respondents reporting car-and-home ownership), significant differences are seen in the methods of walking to school ($X^2 = 206.8$, $df = 36$, $P < 0.0001$) and average number of streets crossed (Kruskal-Wallis = 77.4, $df = 9$, $P < 0.0001$). Removing children who are driven to and from school does change the magnitude of city region differences, but they remain significant (Kruskal-Wallis = 53.65, $df = 9$, $P < 0.0001$); this finding is likely the result of differences in the size of streets, traffic speed, and density of streets in different areas of the city.

There is a significant inverse correlation between the proportion of children driven to and from school in a region and the average number of streets crossed during the day in that region ($r = -0.70$, $P < 0.05$). This is likely because of children not walking during the afternoon.

## Correlation with Pedestrian Collision Data

Pedestrian injury data from the city of Baltimore were compared with survey data on traffic exposure. Table V summarizes the rate of pedestrian collisions in the 10 city regions. The overall pedestrian collision rate is 5.0 per 1000 children in this age group; the range is from 0.9 per 1000 children in the lowest region to 13.4 per 1000 children in the highest region. The poorest regions of the city tend to be those with the highest exposure to traffic, because children are likely to walk and not be driven. Five of the six wealthiest regions have pedestrian injury rates below the city average (5.0 per 1000 children); the four poorest regions all are significantly above the city average.

We correlated the rate of pedestrian injury, based on 1993 data, with traffic exposure for each region. There is a significant inverse correlation between the rate of pedestrian injuries and the proportion of children driven home from school ($r = -0.79$, $P < 0.01$); if a region has a large percentage of children being driven home, there is less chance of pedestrian injury. Being driven home from school appears especially important, as the peak time for pedestrian injuries is between 2 and 4 PM.

Fig. 1 displays the regions of Baltimore having the highest pedestrian injury rates; superimposed is a designation of the poorest regions, as measured by car-and-home ownership. There is notable overlap between the areas of low wealth and high pedestrian injury rates.

## *Discussion*

Children being struck by cars as pedestrians is a significant urban health problem. Many different explanations are given for this phenomenon, including those that assess the problem as a behavioral issue of the children being injured.[17] This study lends support to an environmental component to pedestrian injury, namely the amount of traffic to which children are exposed.

Using cross-sectional survey data concerning how children get to and from school and their exposure to traffic via crossing streets, we explored potential associations with risk of pedestrian injuries. Comparisons across regions of a city were performed to assess group differences in these factors.

This study demonstrates great variation across city regions in the ways that children travel to and from school. Almost all children are driven to school in some areas of a city; in other areas a majority of children walk to and from school, many of them without the supervision of an adult. Children in fourth grade seem

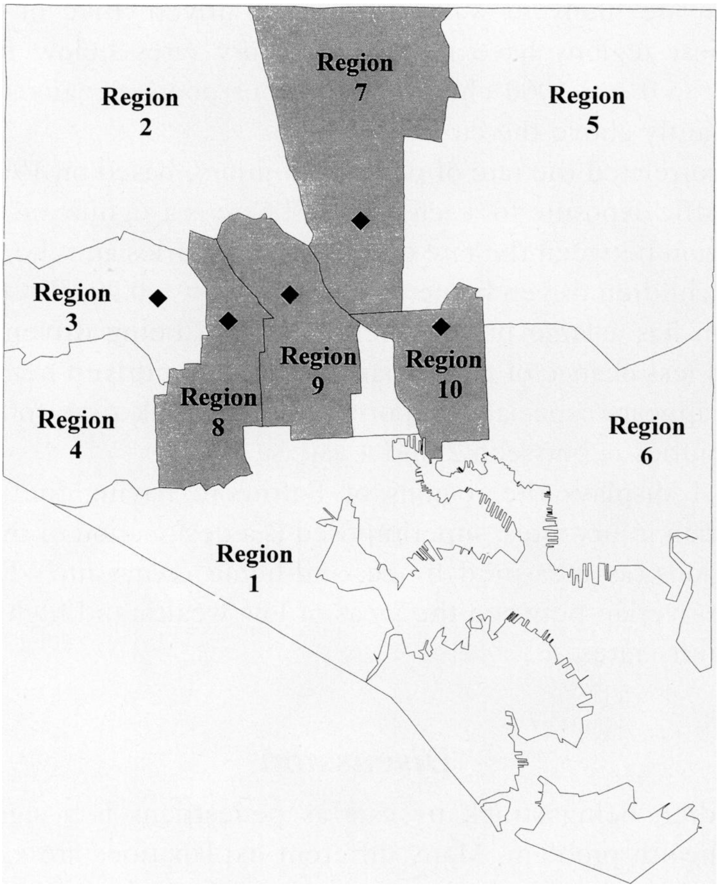


FIG. 1. Shaded area indicates regions where car and home ownership are lowest. ◆, Regions where pedestrian injury rates are greater than 8.0 per 1,000 children.

to have higher exposure to traffic than children in first grade, based on the percentage of children who walk alone and the number of streets they cross.

Urban streets are not homogeneous, however, just as urban neighborhoods are not homogeneous. In addition to differences across neighborhoods in the quantity of small and larger streets, large streets may differ in separate regions of a city in terms of speed limits, number of stoplights, and frequency of pedestrian travel. Neighborhoods often differ in the amount and speed of traffic; this is related to many context-specific factors, such as proximity to downtown business districts, connections to interstate highways, and average household wealth of the neighborhood.

The differential in traffic exposure appears associated with the differential in rates of pedestrian injury across the regions of the city created for analysis in this study. While car and home ownership may serve as a proxy for poverty, it may also be an indicator of other unmeasured risk factors. This study suggests that the relationship between poverty and pedestrian injury may be explained, in part, by differences in parental home and car ownership—children living in poverty were more likely to be exposed to greater amounts of traffic.

There are several key limitations to this research. The first and most notable is the ecological design of the study. Data were compared across groups, but not for the same individuals. Second, the response rate to this survey was poor. Whereas the response was consistent across areas of the city, it was consistently low. Significant selection bias may be present in those parents who chose to complete the survey.

If a selection bias exists, it could be in several possible directions. First, children in families who consider themselves to be "low risk" could choose not to complete the survey. If so, these results may severely overestimate the average number of streets crossed if parents of children driven to school did not complete the survey. Children in families who consider themselves "high risk" might also choose not to participate for a separate set of reasons. If so, the findings may underestimate traffic exposure if children if parents of children who walk to school did not complete the survey.

An alternate explanation for the poor response rate and potential selection bias may be the complicated process by which the surveys were distributed and collected according to the arrangements made with school administrators; difficulty with any step of the distribution or collection could result in a poor response rate. Problems in implementation of the survey by principals and teachers would likely result in a poorer overall response rate, but would likely be non-differential in that children from low-risk and high-risk families within the school would both be affected.

Under ideal circumstances, a second copy of the survey would have been sent to children who did not return the first one, to maximize response rate. In addition, a sample of non-responders could have been identified and surveyed to assess potential bias in respondent characteristics. Due to constraints of confidentiality, these methods were not used.

A third limitation of this research is the incomplete details on environmental issues relevant to the study of pedestrian injuries. For example, weather may play a role in how children get to and from school, so that on sunny days exposure to traffic may be quite different than exposure to traffic on rainy days. The sampling design of the study did not draw sufficient data on rainy days to make adequate comparisons. In addition, this study did not attempt to distinguish characteristics of actual roads in terms of speed limits, presence of stoplights, etc. Regions of the city were characterized only in terms of rates of injury and information available from the survey.

Finally, this study does not attempt to assess the possible presence of another unknown variable that may mediate or be confounded with traffic exposure and risk of pedestrian injury. High traffic exposure during school days may be correlated with some other exposure that places children at risk for pedestrian injury.

Despite these limitations, the findings of this study are relevant to prevention of pedestrian injuries. This study presents pedestrian injuries not as a random phenomenon, but as a pattern of events. Injuries are more frequent in certain neighborhoods compared with others. At the very least, these data can be used to raise consciousness within particular neighborhoods regarding the prevalence of pedestrian injuries. Environmental characteristics of these neighborhoods may be altered to reduce children's exposure to hazards. Although individually educating all children about traffic safety has been attempted for many years, evaluation efforts have shown that such education programs have only limited success in reducing pedestrian injuries.[18,19]

Several European nations have developed approaches to reducing pedestrian injuries that focus on environmental modifications, with notable success.[19] These include reducing motor vehicle traffic volume in areas of pedestrian activity and separation of busy traffic from residential areas. Although such efforts require the cooperation of urban planners, engineers, and several other parties, environmental modifications represent one way to reduce the magnitude of this urban health problem in the United States.

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